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DETECTION THRESHOLD OF THE LASA/SAAC SYSTEM

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13 ABSTRACT

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At LASA the 90 percent discrete threshold occurs at magnitude 3.9, and the 90 percent cumulative threshold occurs at magnitude 3.7 for events within 30° to 85° of LASA. The detection rate varies inversely with the noise level and is somewhat lower in the late autumn than it is during the summer when the noise is lower.

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ABSTRACT

An estimate of the detection threshold of a seismic observatory can be obtained from recurrence curves. Since we expect small events to occur more frequently than larger events, a plot of the number of events detected at LASA versus their magnitude over a long interval of time will fail to increase as magnitude decreases when the detection threshold is reached and small events are lost in the noise.

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INTRODUCTION

The large seismic arrays were designed to improve the signal-to-noise ratio and weak signal detection for teleseismic earthquakes and explosions. This past year at SAAC our primary objective has been to evaluate the SAAC/LASA system. A key part of this evaluation is measuring the detection threshold of teleseismic P-waves generated by events with epicenters between 30° and 90° from LASA. Moreover we wish to determine whether this detection threshold depends only upon the seismic noise background at LASA or whether it is limited by the ability of the hardware, software, or analysts at SAAC to keep up with the volume of data processing required.

The method we followed during this evaluation period was to operate SAAC and publish the LASA Event Bulletin as close to full time as possible. We set the detection-analysis threshold for signals at a fixed signal-to-noise ratio, S/N = 5/1 (or 14 db) and attempted to analyze every signal crossing this threshold including the signals from the swarms of aftershocks following large earthquakes. Since we expect small earthquakes to occur more frequently than larger events, the weak signal threshold of the system is indicated by plots of the number of events versus magnitude. When the number of events detected fails to increase as the signal size decreases, the system threshold has been reached.

SAAC OPERATIONS

Currently there are three large seismic arrays feeding data to SAAC (Figure 1). Two of them, ALPA and NORSAR, are essentially sources of long period (LP) information. Only three channels of short period data arrive at SAAC on-line from NORSAR. These are not sufficient for an earthquake bulletin. Hence the earthquake bulletin published daily at SAAC reports events detected only on the short period sensors at LASA and is known as the LASA Daily Summary.

The system operates in two parts. The Detection Processor in the on-line computer performs data acquisition and signal detection. The Event Processor in the off-line computer is designed to recognize true signals and false alarms and to extract event parameters, refine locations, and prepare the earthquake bulletin. The Event Processor is programmed to work either in the automated mode in which the computer analyzes events and publishes the bulletin without help from a seismic analyst, or to act as an aide to the analyst who can edit the event processing on a display console.

The regions of the earth monitored by LASA are shown in Figure 2. The primary range for teleseisms is from 30° to 90°. A few events closer than 30° appear in the LASA Daily Summary but local events are rejected as false alarms. Events between 90° and 105° which are detected are listed but no attempt is made to detect and locate events from PKP or other core phases.

The detection logic applied to the filtered

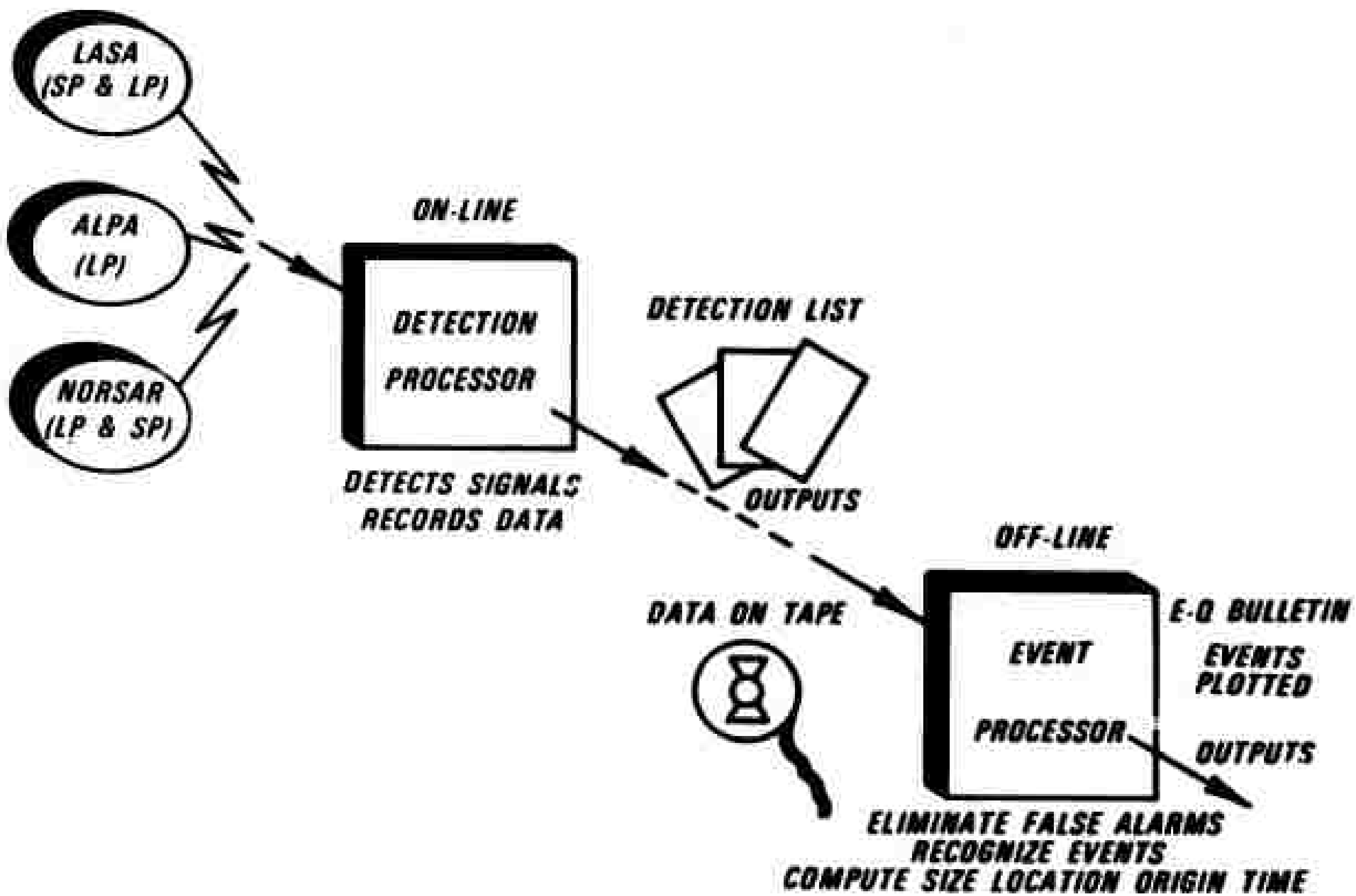


Figure 1. SAAC operations.

Figure 2. P range monitored by LASA.

(0.9 to 1.4 Hz) teleseismic beams works on the basis of signal-to-noise ratio. The on-line computer detects signals exceeding the background noise level (RMS) by 10 db (S/N of 3.2/1). There is some duration logic also which requires the signal to last for 2.0 seconds or so, but essentially signals exceeding the noise level by 10 db are listed. Figure 3 shows the cumulative number of detections exceeding various signal-to-noise levels with 100 percent at approximately 10 db. With the background noise on LASA beams at 0.1 millimicrons (RMS) this detection threshold yielded an average of 550 detections per day throughout 1971.

We have operated the Event Processor so that it will analyze only detections exceeding 14 db, that is, those with a signal-to-noise ratio of 5 to 1. As seen on Figure 3, this 14 db threshold reduces the number of signals analyzed to 29 percent of those detected.

Figure 4 shows the number of events listed in the LASA Daily Summary versus day of the year. Since May an average of 30 events per day are listed with as many as 80 or 90 on days with large numbers of after-shocks from large events. The analysts spend an average of 5 hours per day editing the events from the previous 24 hours with the system operating at its current thresholds.

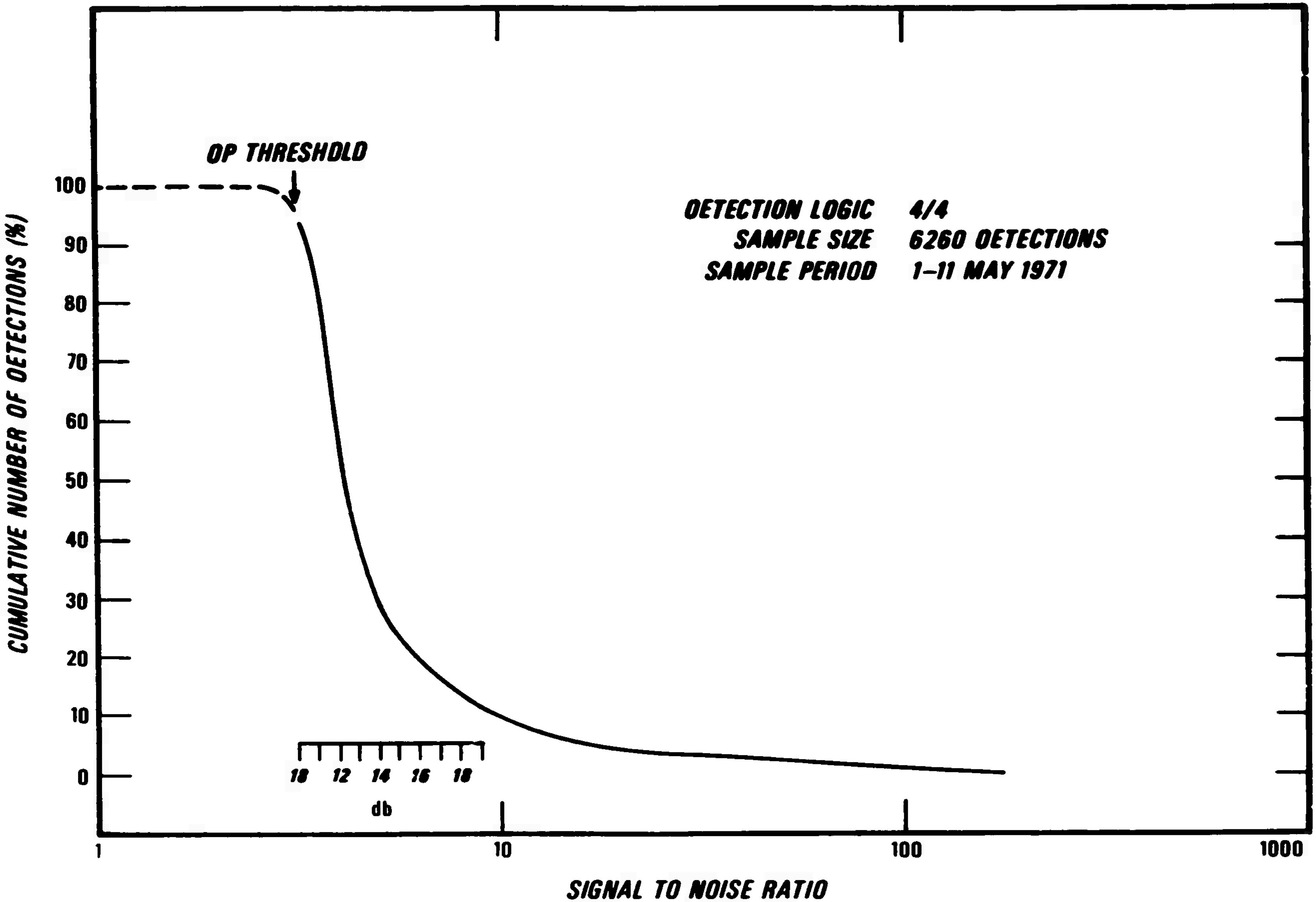


Figure 3. Cumulative number of detections versus signal-to-noise ratio.

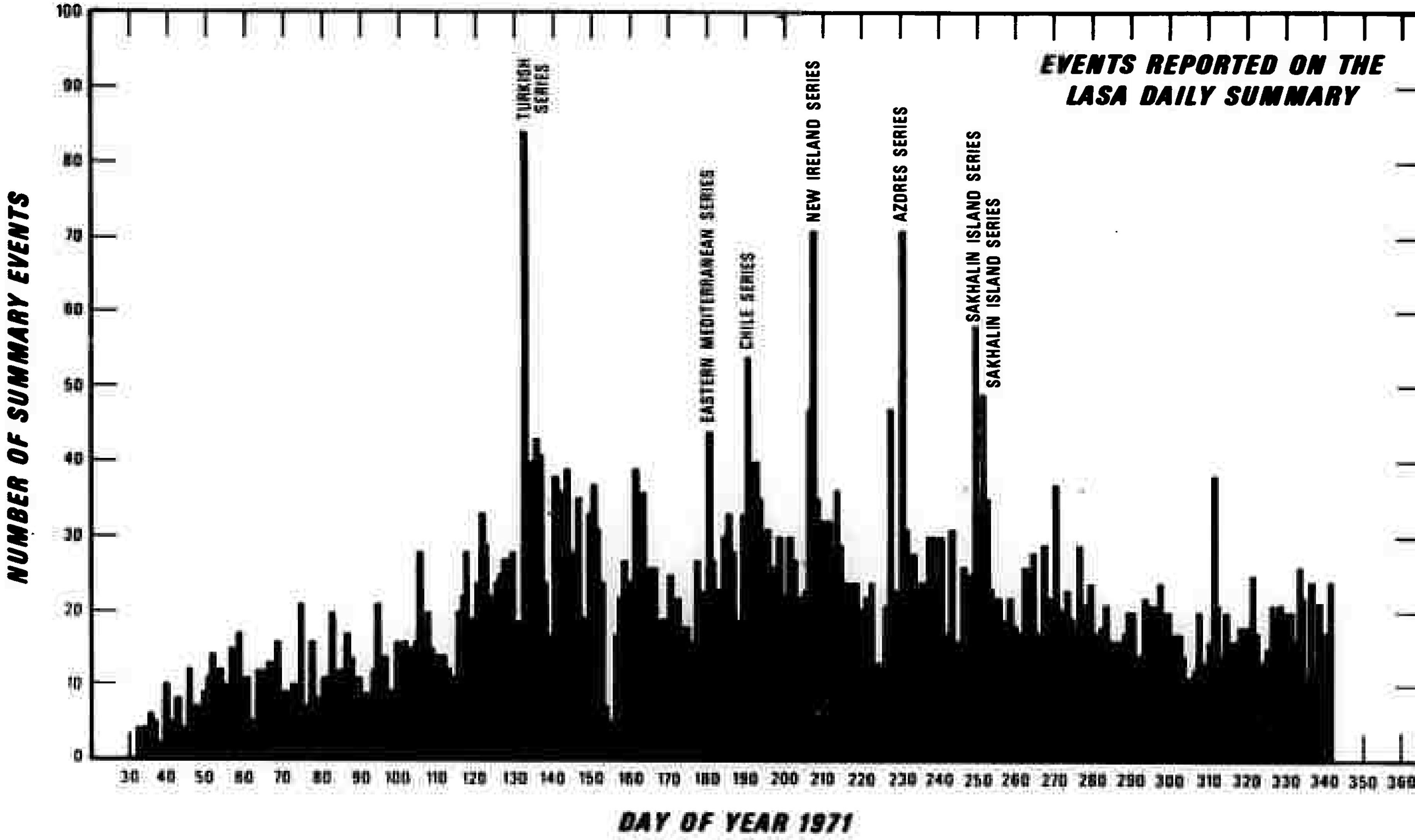


Figure 4. Events on LASA Daily Summary vs day of the year.

DETECTION THRESHOLDS

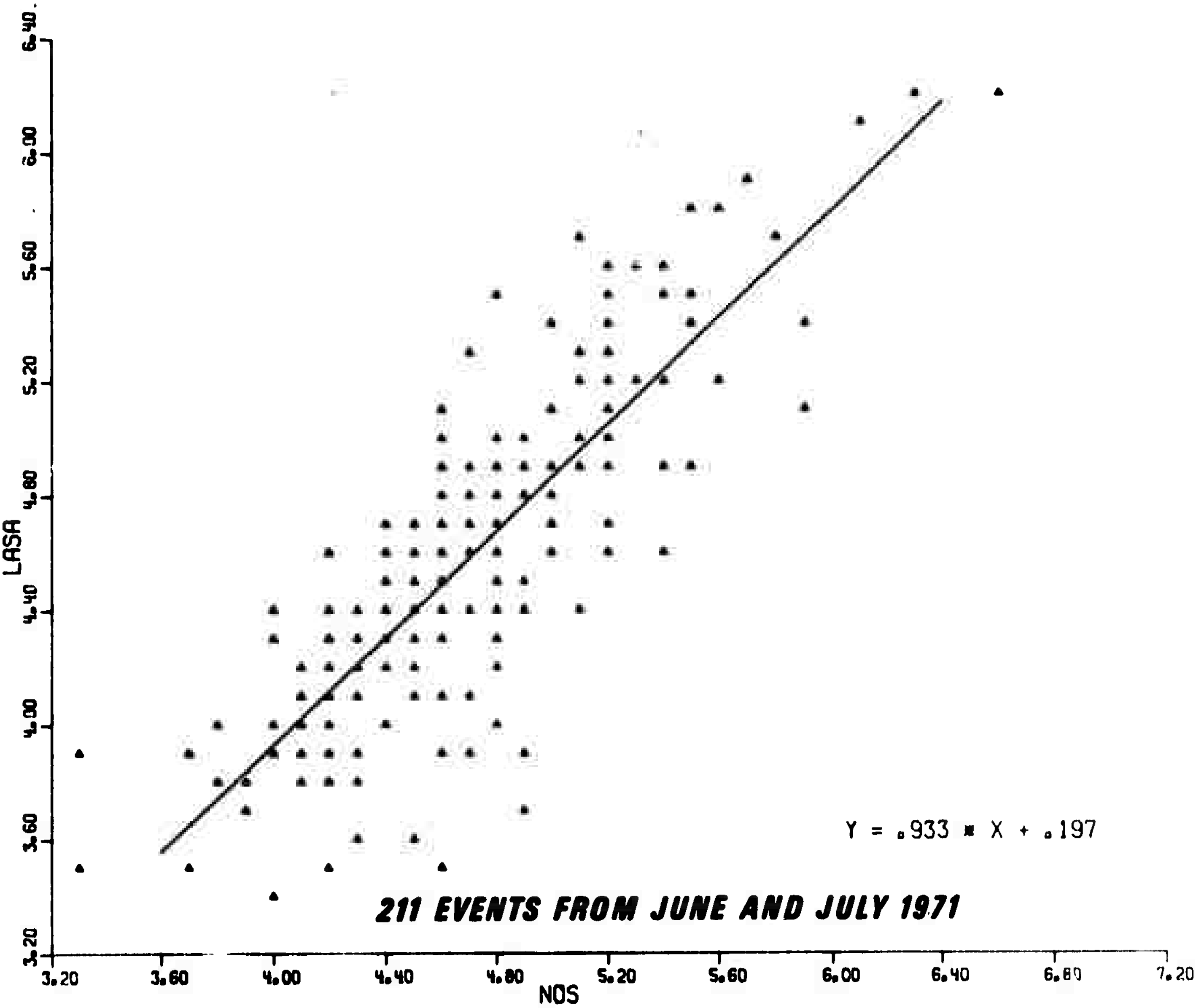
In discussing the threshold of LASA the magnitudes we quote essentially match the NOS scale. Figure 5 compares magnitude estimates for 211 common events listed by the LASA Daily Summary and by NOS during June and July 1971. The LASA magnitudes in terms of NOS magnitudes for these events are given by

$$m_L = 0.933\ m_{NOS} + 0.197$$

Thus, LASA magnitudes tend to be slightly lower than NOS magnitudes for events greater than magnitude 3.2.

The detection threshold will vary inversely with the noise level. Figure 6 shows the correlation of hourly detection rates for the on-line system at 10 db with the hourly noise level at LASA. As the noise level increases during the daylight hours at LASA, the detection rate goes down. Thus the detection threshold at LASA is slightly higher in the winter when the noise is higher than for the summer months.

The recurrence curves for 508 events recorded during May 1971 are shown on Figure 7. The cumulative curve plots all events on the LASA Daily Summary between 30° and 85° from LASA which are greater than magnitude m_L versus the LASA magnitude m_L. The discrete curve plots the number of events of magnitude m_L versus m_L. We expect the number of events occurring to increase continually as the event magnitude decreases. The actual events reported by LASA, or any seismic observatory,



DISTANCE IS BETWEEN 30 AND 85 DEGREES

Figure 5. NOS vs LASA magnitudes for common events.

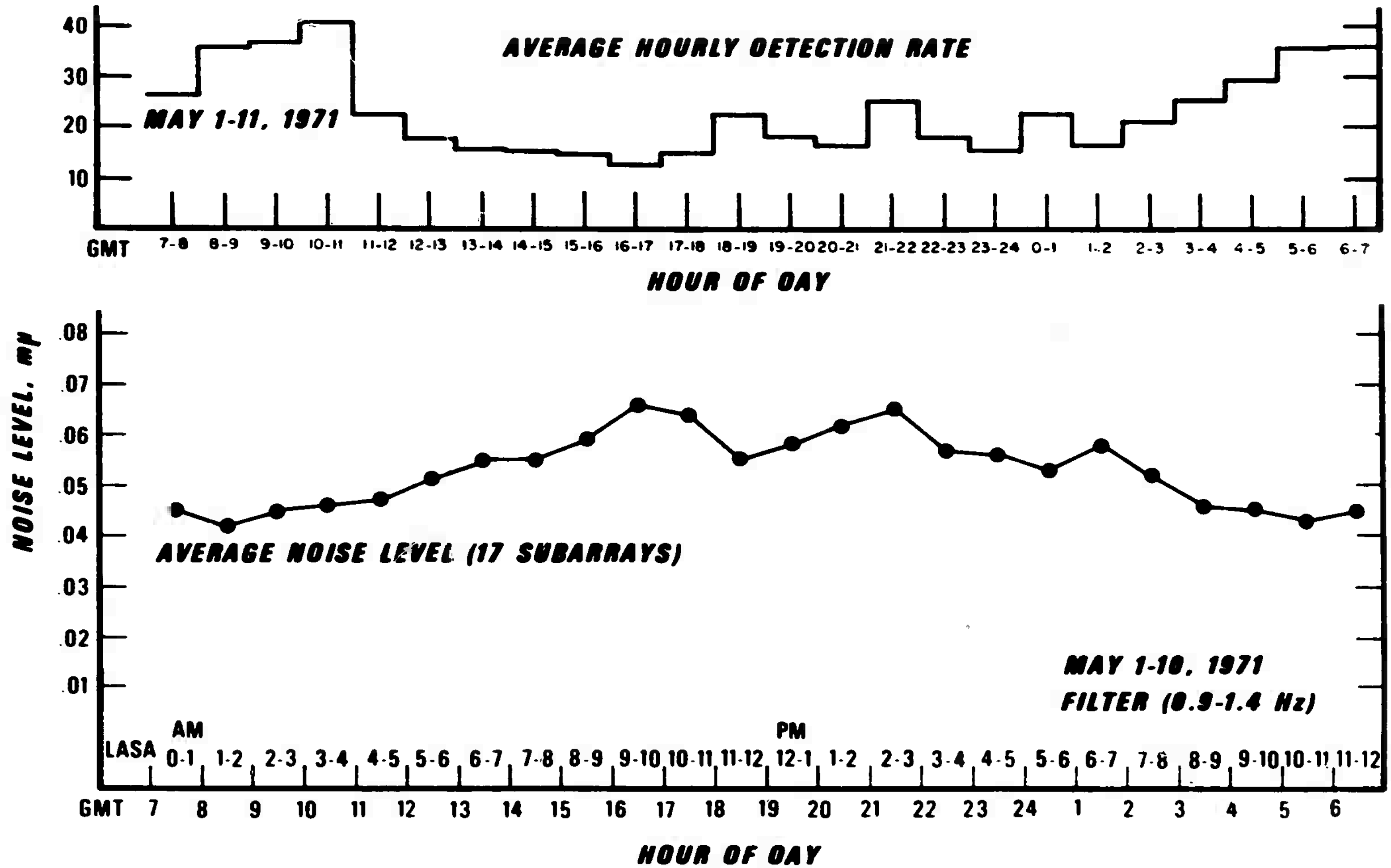


Figure 6. Noise and detections at LASA vs time of day.

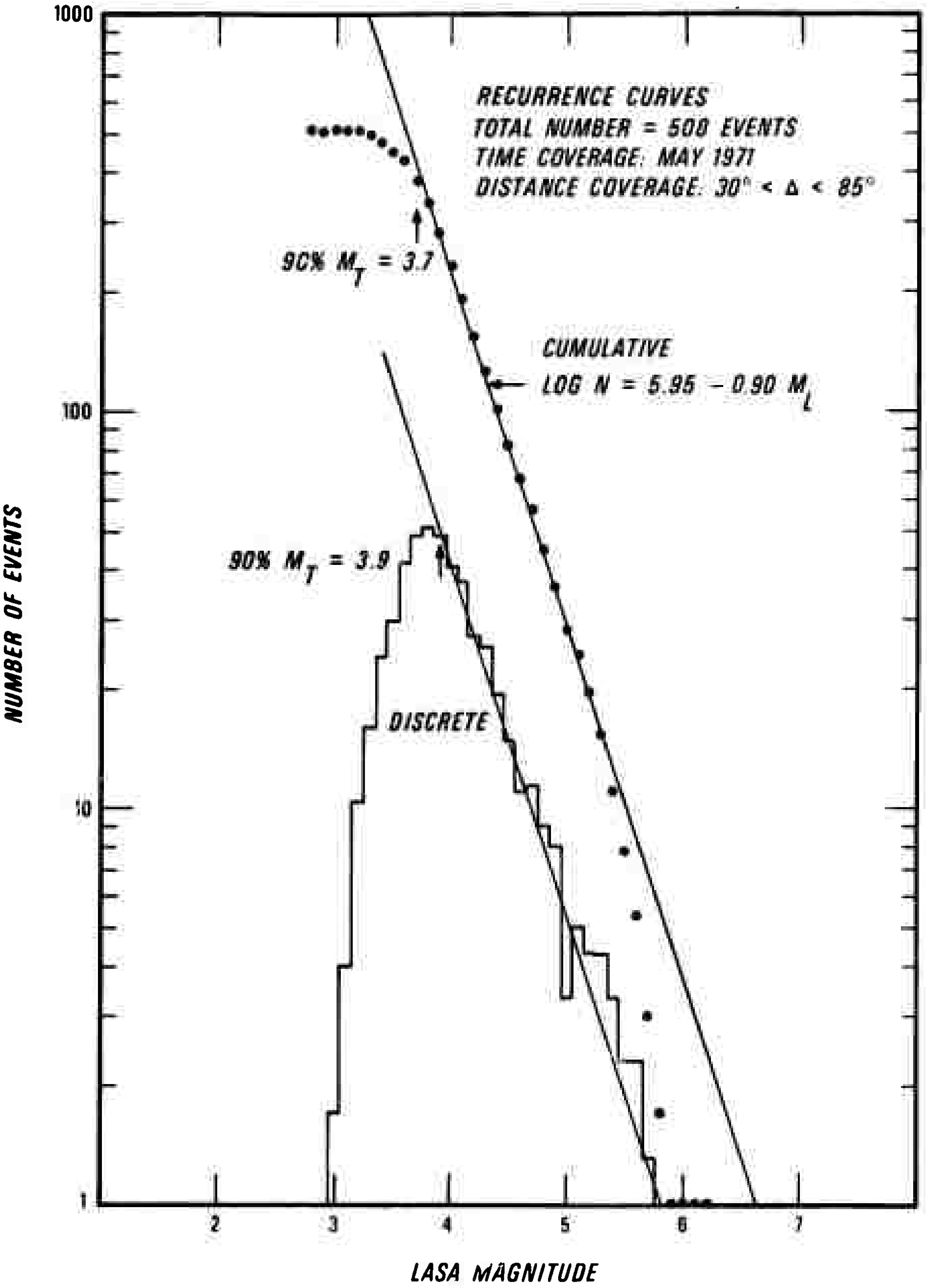


Figure 7. Recurrence curves, May 1971.

fails to follow the straight line trend as the weak signals get lost in the noise. We define the 90 percent threshold as the point where the actual number of events reported is 90 percent of the total expected by extrapolating the trend line to lower magnitudes. For May events the 90 percent threshold occurs at magnitude 3.7 for the cumulative curve and magnitude 3.9 for the discrete.

The expected signal-to-noise ratio at LASA for teleseismic signals at the 90 percent detection threshold (m_b = 3.9) is much higher than the operational 5/1 (14 db) threshold setting in the computer doing the event processing. If we assume:

the period, T = 1.0 second
the B factor = 3.5

then

$$m_b = \log (A/T) + B$$
$$3.9 = \log (A/1.0) + 3.5$$
$$\log A = 0.4$$

so the expected signal, A, (zero-to-peak) is 2.5 millimicrons. The noise level on teleseismic beams at LASA is 0.1 millimicrons (RMS) so the expected signal-to-noise ratio for 90 percent threshold signals is 25/1, well above the operational threshold of 5/1.

There are two reasons for this effect: one is the result of the statistical scatter of signal amplitudes and the second is the result of miscalibrations in the LASA/SAAC system.

If we were to compare LASA's event list with that

from a sensitive NOS network or perhaps a sensitive, well-calibrated local network in a region a teleseismic distance from LASA, we would find the LASA magnitudes higher than the network magnitude on some events and lower on others. The scatter tends to be normally distributed in magnitude with a standard deviation of approximately 0.3 magnitude units. Consequently, of all events reported by our hypothetical network and expected to arrive at LASA with a signal-to-noise ratio equal to the 14 db computer threshold (S/N = 5/1), the LASA/SAAC system will report only 50 percent, namely those which arrive with S/N equal to or greater than 5. The group of events reported by our hypothetical network would have to be 2.5 times (0.4 magnitude) larger in order for LASA to detect 90 percent of them. The expected signal-to-noise ratio at LASA for this set of events would be 12.5/1. These two cases are illustrated on Figure 8.

The second cause of the signals at the 90 percent detection threshold having such a high signal-to-noise ratio is the miscalibration of teleseismic beams. The travel-time corrections which the system has used throughout 1971 are incorrect. Chiburis and Hartenberger (1967) point out that correct travel-time anomalies can improve beam signal-to-noise ratios in large arrays by 2 to 1 (5 to 7 db) over none or incorrect anomalies.

Hence both factors together (2 to 1 due to signal loss in beamforming plus 12.5 to 1 due to scatter of event signal amplitudes) account for 25 to 1 expected signal-to-noise ratio for events at the LASA 90 percent discrete detection threshold.

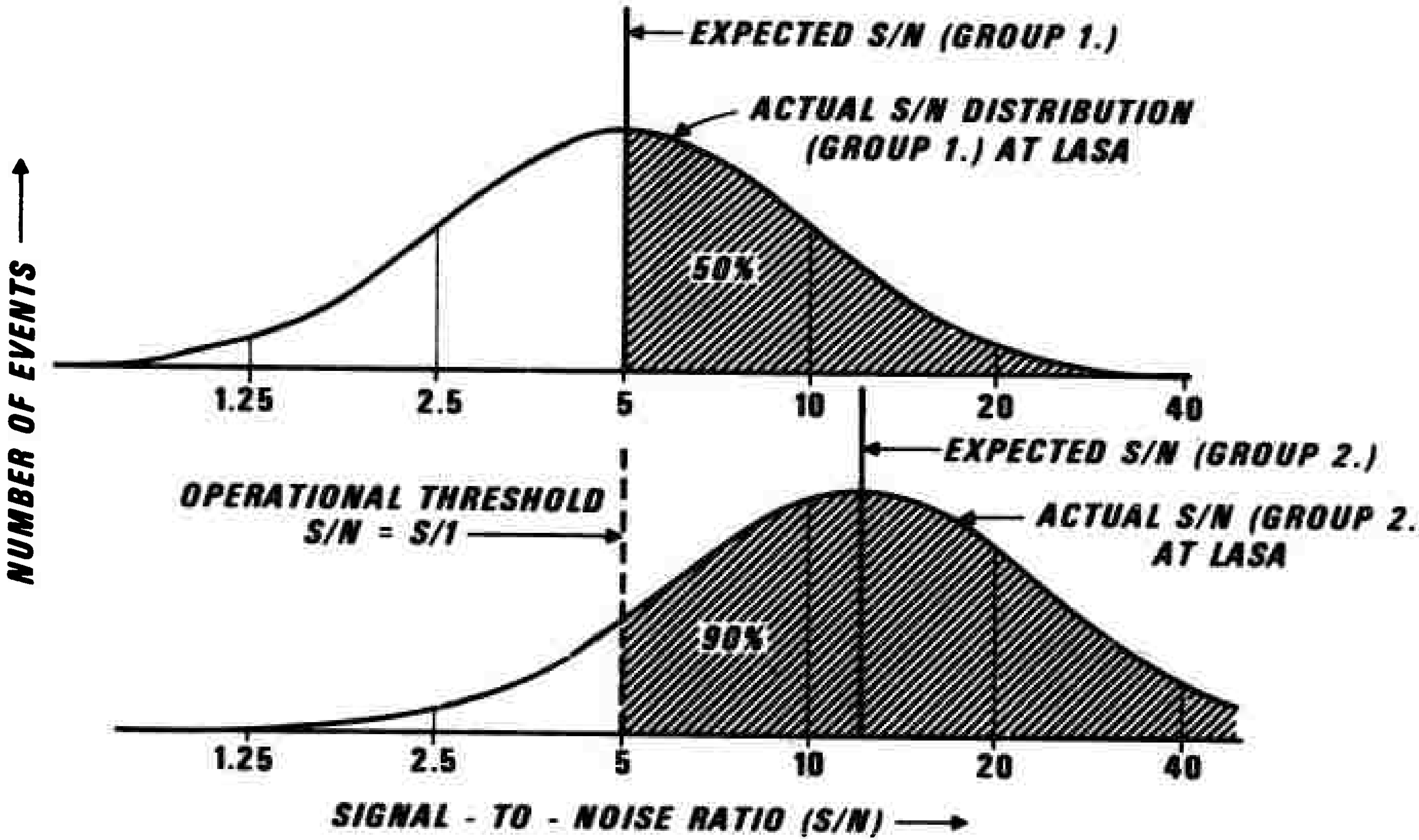


Figure 8. Distribution of S/N's at LASA vs two expected S/N's greater than LASA's operating threshold.

CONCLUSIONS

As we operated the SAAC/LASA system during 1971 the 90% detection threshold as indicated by the cumulative recurrence curve is 3.7 and as indicated by the discrete recurrence curves is 3.9 for events within 30° to 85° of LASA.

The detection threshold is limited by the seismic noise background and not the computer or analyst ability to handle the data processing loads at least where the analysis threshold is set at a signal-to-noise ratio of 5/1.

The detection threshold is strongly affected by background noise levels and increases during periods when large earthquake signals or other seismic activity is present in the array.

The computer threshold setting of the SAAC/LASA system is expected to detect only 50% of the events at that threshold due to magnitude scatter. To detect 90% of the events at a given magnitude requires the computer threshold setting to be 0.4 times the signal-to-noise ratio expected at the 90% threshold.

During 1971 the SAAC/LASA system operated with incorrect travel-time anomalies. Recalibrating the teleseismic beams could improve the detection threshold by 5 to 7 db.

REFERENCES

Chiburis, E.F. and Hartenberger, R.A., 1971, Signal-to-noise ratio improvement by beamforming LASA seismograms: Seismic Data Laboratory Report No. 173, Teledyne Geotech, Alexandria, Virginia.